

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY)

2. REPORT TYPE
Technical Papers

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

2302

5e. TASK NUMBER

MIG2

5f. WORK UNIT NUMBER

346120

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION
REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S
ACRONYM(S)11. SPONSOR/MONITOR'S
NUMBER(S)

Please see attached

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030128 233

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

a. REPORT

Unclassified

b. ABSTRACT

Unclassified

c. THIS PAGE

Unclassified

17. LIMITATION
OF ABSTRACT

A

18. NUMBER
OF PAGES19a. NAME OF RESPONSIBLE
PERSON

Leilani Richardson

19b. TELEPHONE NUMBER
(include area code)

(661) 275-5015

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

16 Mar 2001

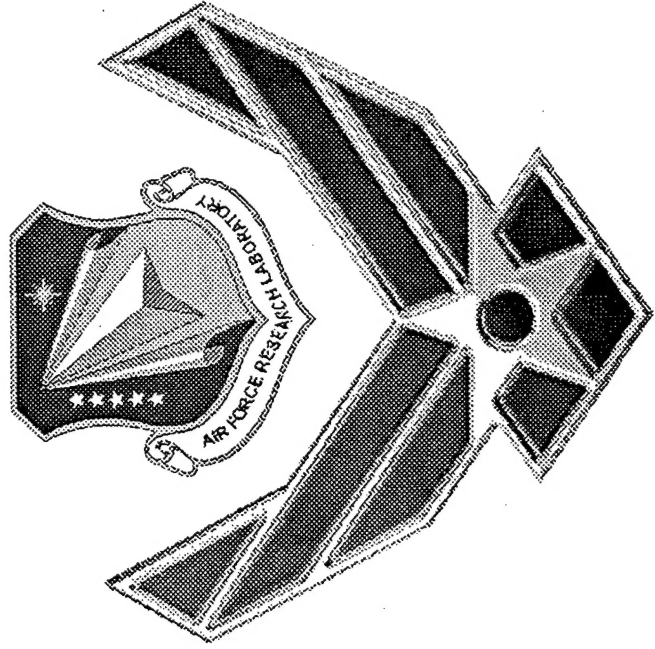
SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-053**
Miller, T.C., "Crack Growth Rates in a Propellant Under Various Conditions" (VuGraphs)

JANNAF 34th Structures & Mechanical Behavior Subcommittee Meeting
(Cocoa Beach, FL, 26-30 Mar 01) (Deadline: 26 Mar 2001)

(Statement A)

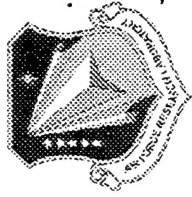
CRACK GROWTH RATES IN A PROPELLANT UNDER VARIOUS CONDITIONS

27 Mar 01



Tim Miller
Engineer

Propulsion Directorate
Air Force Research Laboratory



Introduction

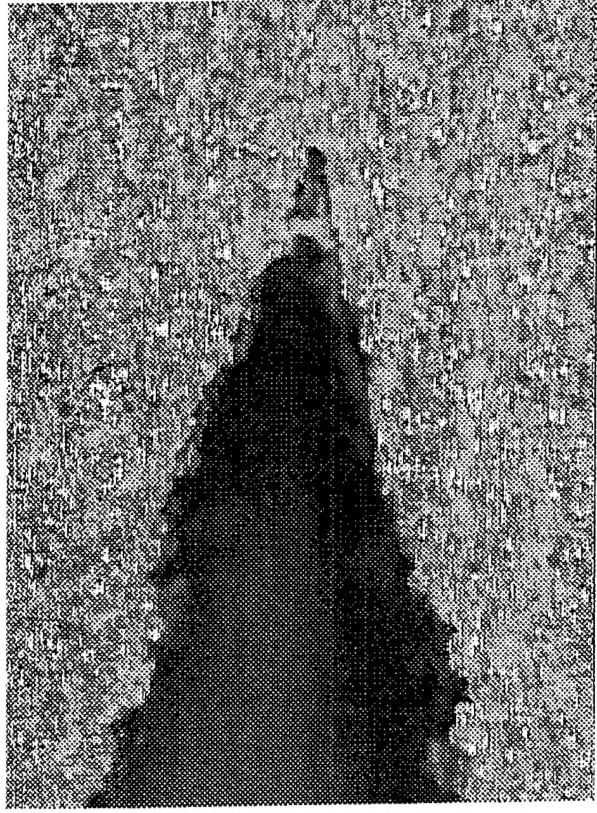
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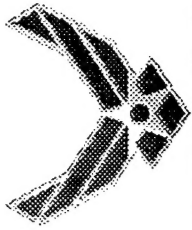
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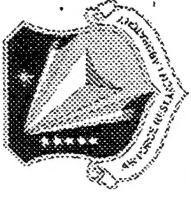
Summary and
Conclusions

- Cracks develop during manufacturing, handling, and storage of rubbery particulate composites
- During the service life, the cracks may begin to grow, but may still be subcritical because the cracks may grow slower than the burn rate of the propellant
- Results for three types of specimens are described. This is done both at ambient and 1000 psi (6895 kPa) pressure.





Complications in Propellant Fracture Analysis



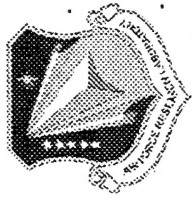
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- Propellant has unusual properties (time dependence, large deformations, inhomogeneous microstructure) and has not been analyzed as thoroughly as more conventional materials
- Conventional experimental approaches do not always work well because of these properties
- Service conditions vary from long-term low stress conditions caused by thermal loads during storage to short-term high stress conditions caused by pressurization during launch



Experimental Procedure

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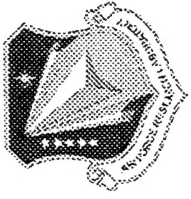
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- Specimen geometries and test matrix
- Test conditions
- Equipment



Specimen Geometries and Test Matrix

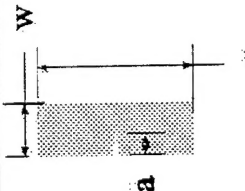
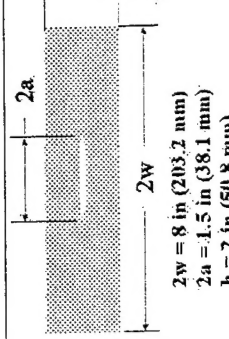
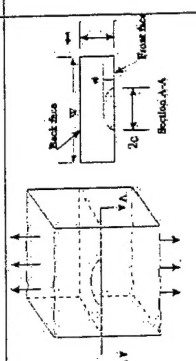


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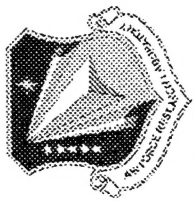
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Specimen Type	Figure	Test Conditions
Single edge notched tension	 <p> $w = 1 \text{ in (25.4 mm)}$ $a = 0.1, 0.3 \text{ in (2.54, 7.62 mm)}$ $h = 3, 5 \text{ in (76.2, 127 mm)}$ $\text{thickness} = 0.2, 0.5, 1.0, 1.5 \text{ in (5.08, 12.7, 25.4, 38.1 mm)}$ </p>	Strain rate = 0.067 in/in/min, ambient pressure, 1000 psi (6895 kPa)
Biaxial stress	 <p> $2w = 8 \text{ in (203.2 mm)}$ $2a = 1.5 \text{ in (38.1 mm)}$ $h = 2 \text{ in (50.8 mm)}$ $\text{thickness} = 0.2 \text{ in (5.08 mm)}$ </p>	Strain rate = 0.100 in/in/min, ambient pressure
Surface cracked	 <p> $a = c = 0.4 \text{ in (10.16 mm)}$ $t = w = 2 \text{ in (50.8 mm)}$ $\text{height} = 2.75 \text{ in (69.65 mm)}$ </p>	Strain rate = 0.067 in/in/min, 1000 psi (6895 kPa) pressure



Test Conditions



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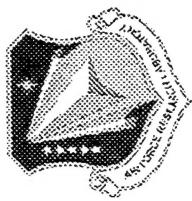
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- **Ambient temperature**
- **Ambient pressure and 6895 kPa pressure (nitrogen gas)**
- **Constant strain rate tests (0.067 - 0.100 mm/mm/min)**



Equipment



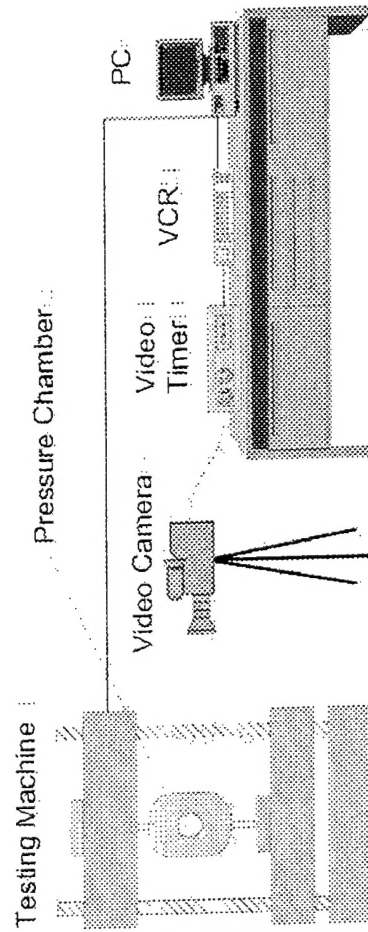
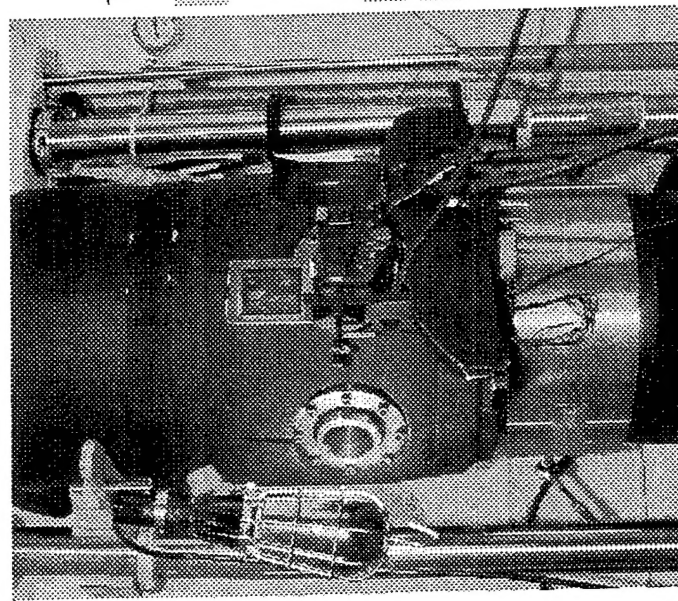
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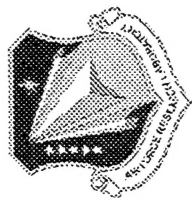
Summary and
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- Testing machine
- Pressure test chamber
- Videotape equipment





Fixture Is Used to Apply Uniform Displacement Boundary Conditions

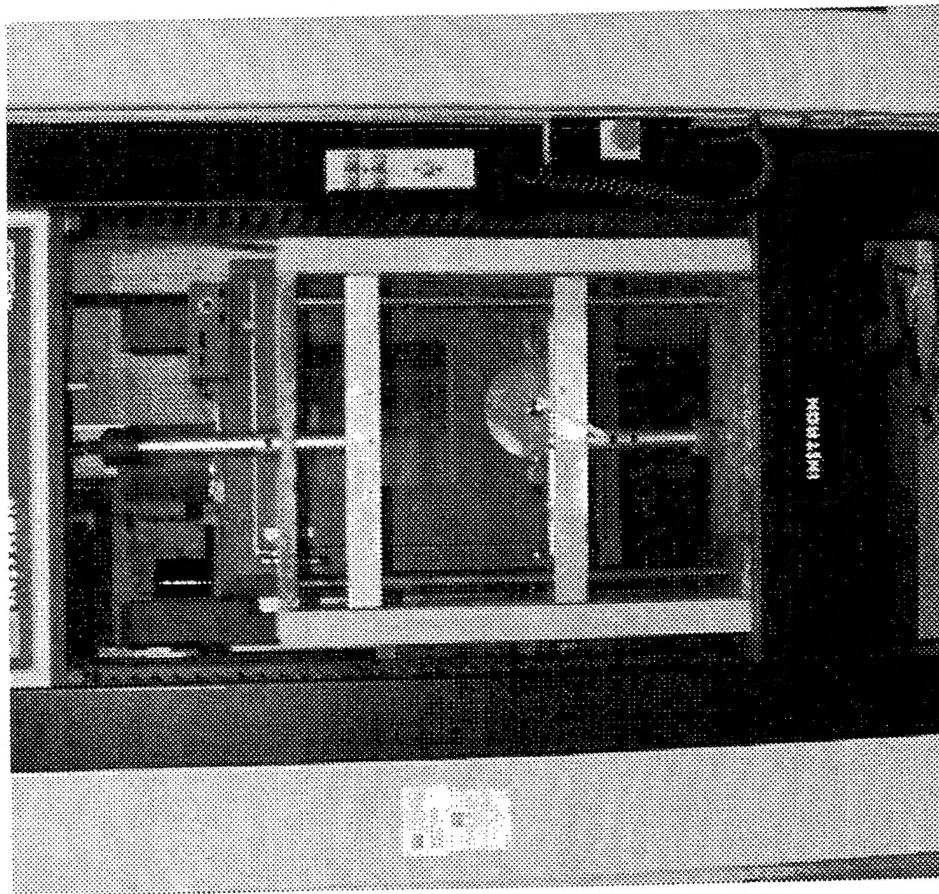


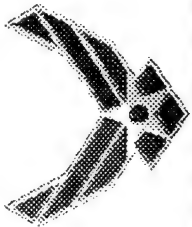
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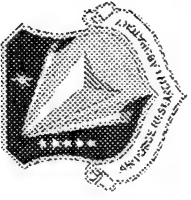
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Flowchart for Experimental Procedure

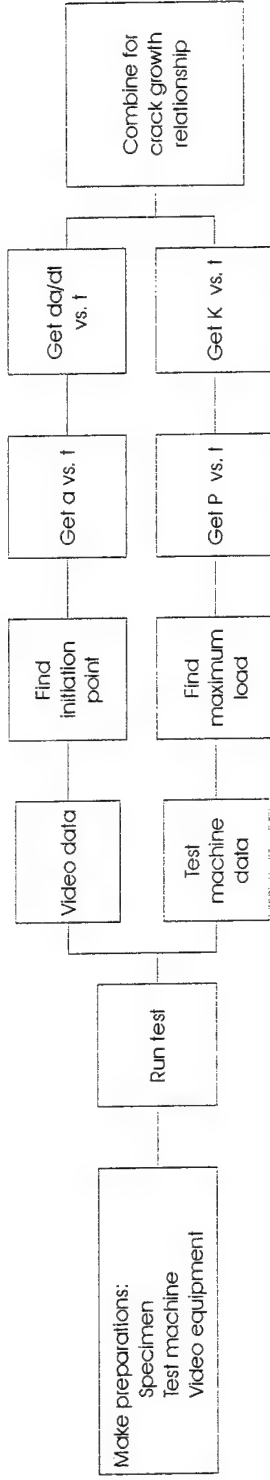


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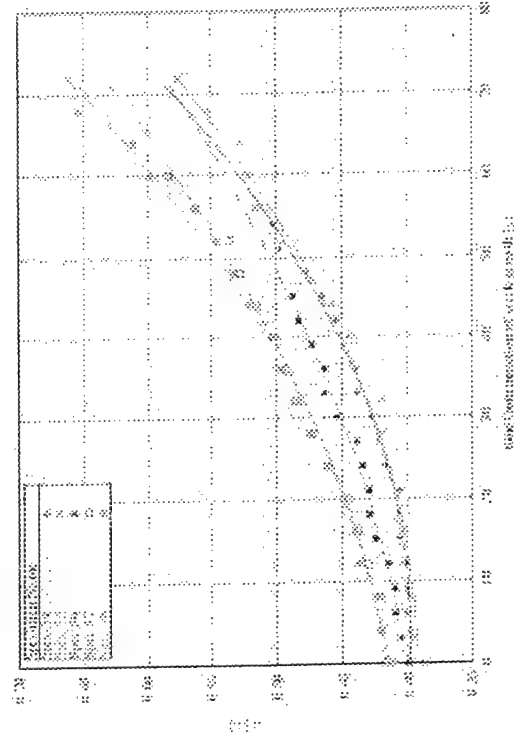
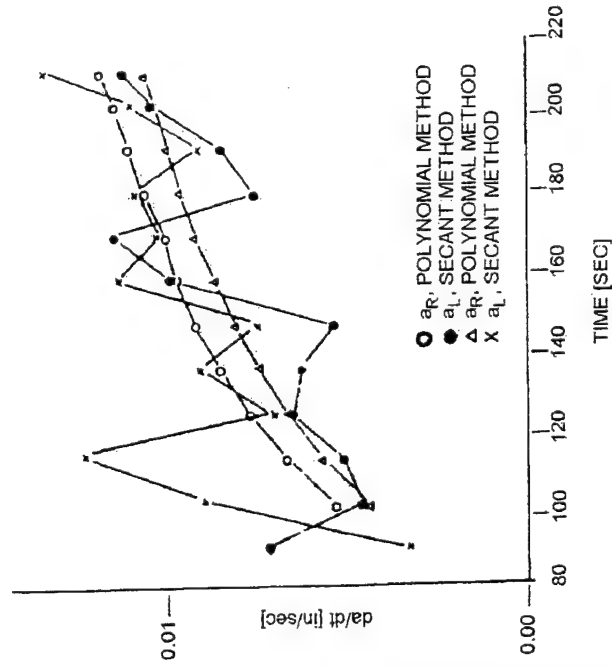
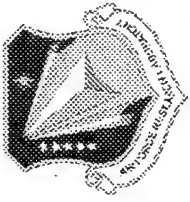
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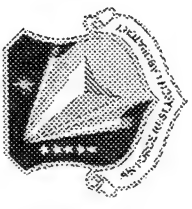
Nonuniform or irregular?

Nonuniform Crack Growth





Results and Discussion



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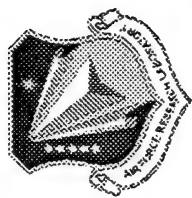
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- Specimen Geometries (SENT, biaxial, surface cracked)
- Pressure Effects



Comparison of Biaxial and SENT Specimen Growth Data



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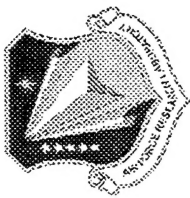
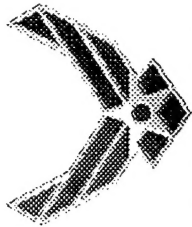
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$$\frac{da}{dt} = C_1 K_I^{C_2} \text{ or } \log\left(\frac{da}{dt}\right) = \log(C_1) + C_2 \log(K_I)$$

Specimen type	$\log(C_1)$	C_2	$K_I = 50 \text{ psi in}^{1/2}$	$K_I = 90 \text{ psi in}^{1/2}$
SENT	-6.030	2.084	0.0028	0.0110
Biaxial	-6.590	2.375	0.0032	0.0113



SENT and Surface Cracked Specimen Comparisons

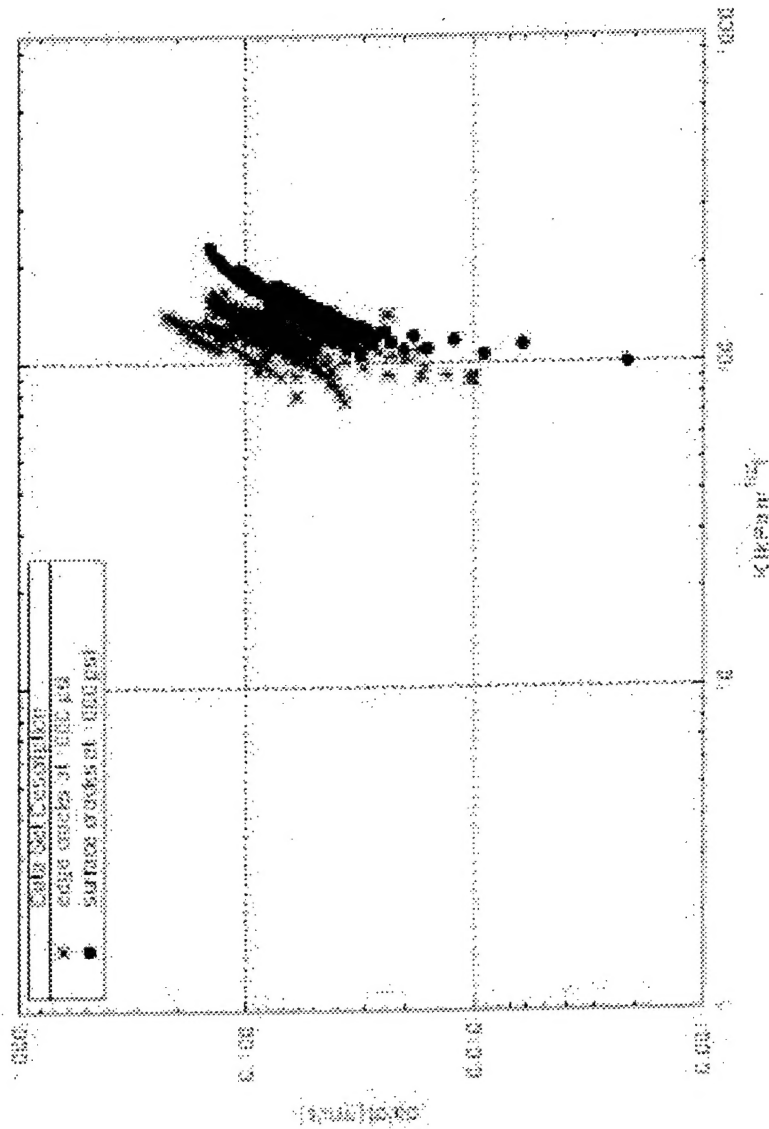
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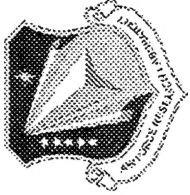
Summary and Conclusions

- Similar growth rates found for both geometries
- Implication: SENT data can be used instead of testing with surface cracked specimens





Ambient Vs. Pressurized Conditions



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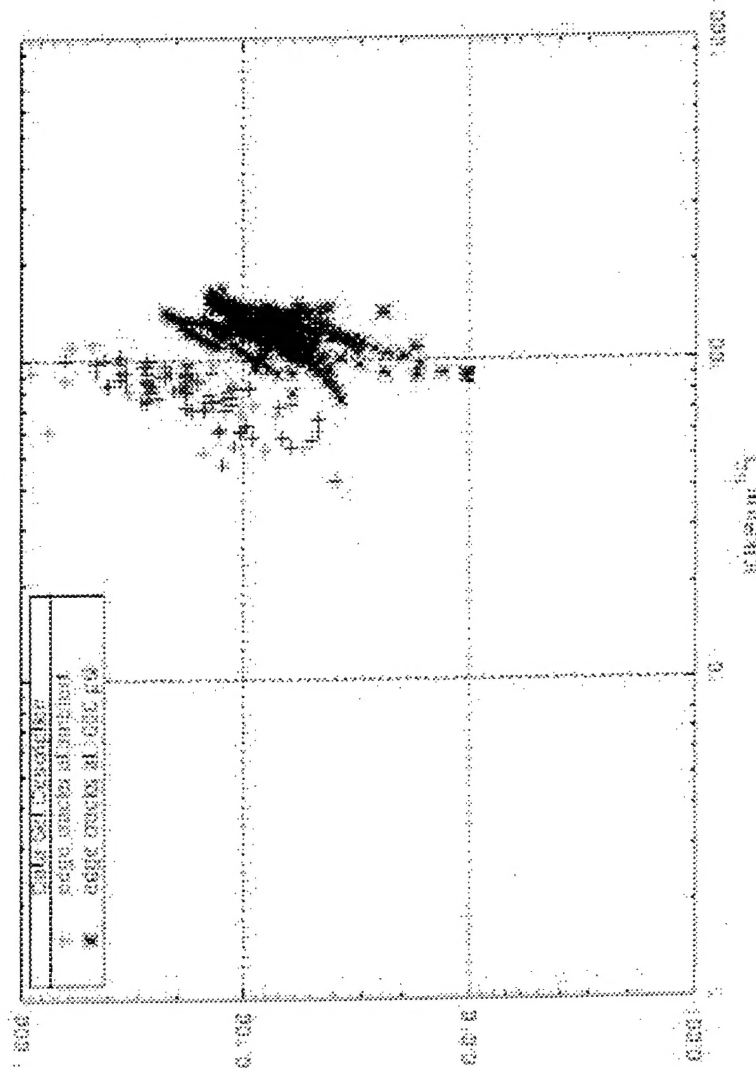
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Procedure

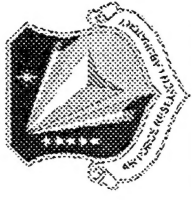
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- Pressure causes crack growth to slow
- Microstructural explanation
- Implication: ambient data may be overly conservative for

...





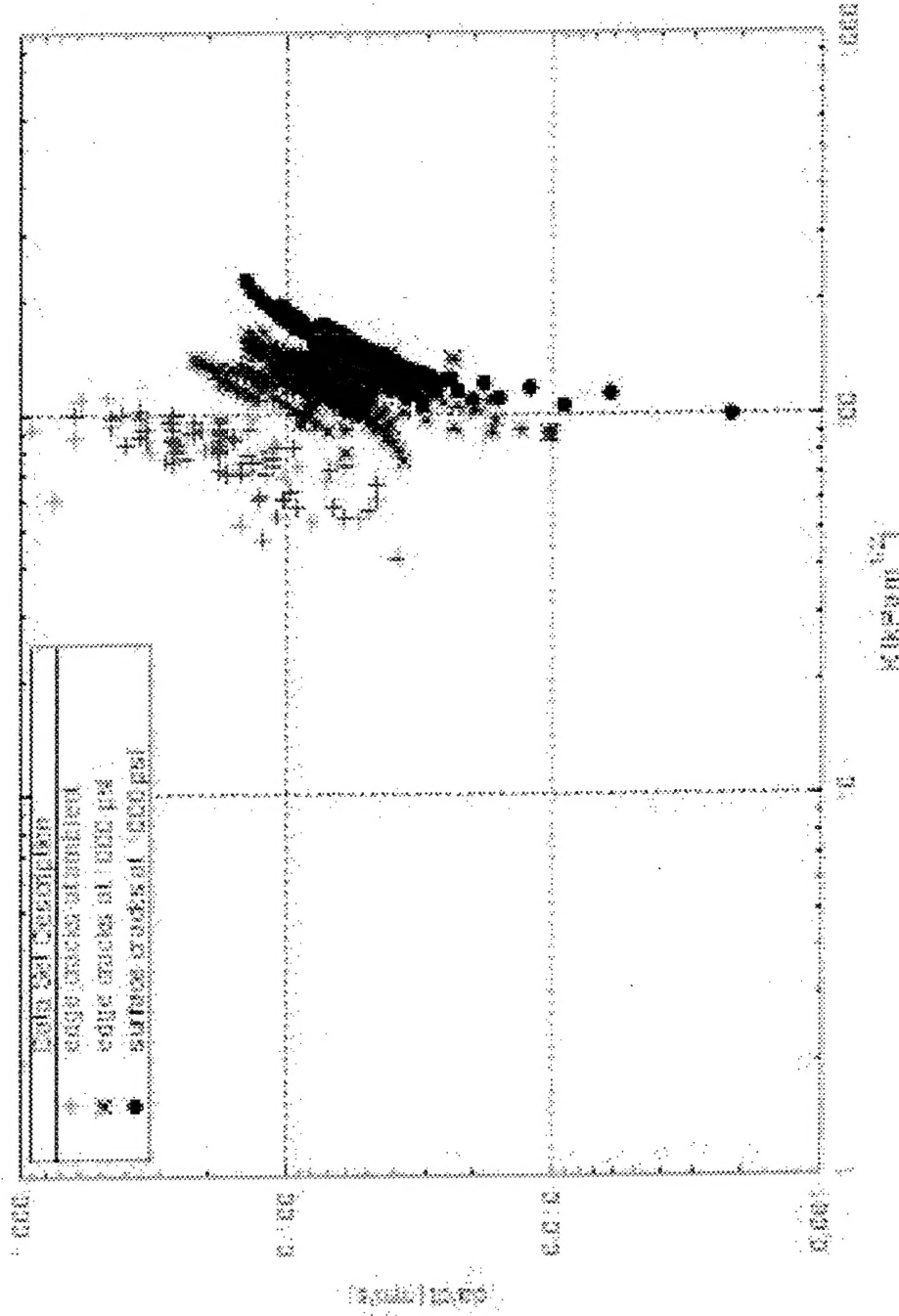
Combination of Data

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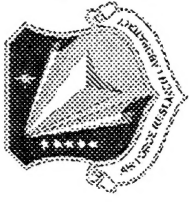
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Summary and Conclusions



- **Summary:** this work has investigated the effect of pressure on fracture behavior of a rubbery particulate composite, and has compared the results for different crack geometries and different pressure conditions. Pressure delays the onset of crack growth and slows the subsequent growth rate. The results for the specimen geometries tested (both at ambient and 1000 psi (6895 kPa) pressure) show good agreement.
- **Conclusions:**
 - Good agreement between biaxial, SENT, and surface cracked specimens
 - Pressure inhibits the start of crack growth and slows the subsequent crack growth
 - Pressurized test data should be used to test for pressurized service conditions